General Physics I: Term Exam (113–1)

100 minutes, full mark = 50

Use of your notebooks/memos/books: Strictly forbidden.
Use of your mobile etc. & Internet: Strictly forbidden.
Discussion with other attending students: Strictly forbidden.

Administrative Remarks

- Write your name and student ID on the answer sheet. Put your student ID on the desk.
- Allowed on your desk: student ID card (required), pens/pencils, correction tools (eraser etc.), rulers, and drinks. **Other items must be stored in your bags.**
- You cannot wear watches nor electronic devices. **You cannot have them even in your pockets**.
- **After 9:10, the following actions are considered cheating. You may immediately lose your credit.**
  - If non-allowed items (pen cases, foods, poaches, etc.) are found on desks.
  - If you have textbooks, mobile phones, tablets, or PC, if they are not stored in your bags, or if you use them. They must be in your bags even after you submit your answer sheets.
- Breaks are not allowed in principle. After 10:00, you may leave after submission. In case of health problems or other issues, call the TA or lecturer.
- *Any form of academic dishonesty, including chats, additions/corrections after the period, and using your phones, will be treated by NSYSU "Academic Regulations."*

Scientific Remarks

- Show your calculations or thought process for **partial mark**!
- Use English, where mistakes are tolerated. Meanwhile, scientific mistakes are not tolerated.
  - Provide appropriate **units** properly. Handle **significant digits** properly.
  - Clearly distinguish **vectors** (by writing $\vec{E}$, $\vec{x}$ or $\mathbb{E}$, $\mathbb{x}$) from scalars (E, x).
- If you find any errors or issues in the questions, explain them on your answer sheet, make necessary adjustments on the question, and answer accordingly.
- You may use the following symbols and values without definition/declaration.

standard acceleration of gravity	g	$= 9.8\,\mathrm{m/s^2}$
Newtonian constant of gravitation	G	$= 6.7\times10^{-11}\,\mathrm{N\cdot m^2/kg^2}$
elementary charge	e (or $\lvert e\rvert$)	$= 1.6\times10^{-19}\,\mathrm{C}$
permittivity of free space	ϵ_0	$= 8.9\times10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$
permeability of free space	$\mu_0 = \left(\epsilon_0 c^2\right)^{-1}$	$= \pi\times4.0\times10^{-7}\,\mathrm{N/A^2}$
Coulomb constant	$k_e = \left(4\pi\epsilon_0\right)^{-1}$	$= 9.0\times10^{9}\,\mathrm{N\cdot m^2/C^2}$
speed of light in vacuum	c	$= 3.0\times10^{8}\,\mathrm{m/s}$
Avogadro's number	N_A	$= 6.0\times10^{23}/\mathrm{mol}$
masses of protons and electrons	m_p, m_e	$= 1.7\times10^{-27}\,\mathrm{kg}, 9.1\times10^{-31}\,\mathrm{kg}$

Unit vectors in the direction of the axes $(\vec{e_x}, \vec{e_y}, \vec{e_z})$ or $(\hat{e_x}, \hat{e_y}, \hat{e_z})$ or $(\hat{i}, \hat{j}, \hat{k})$

$\vec{E}(\vec{x})$ electric field at $\vec{x}$ $\quad$ $\vec{B}(\vec{x})$ magnetic field (magnetic flux density) at $\vec{x}$
$V(\vec{x})$ electrostatic potential at $\vec{x}$ $\quad$ $\vec{F}_{XY}$ force exerted by X on Y

$\sqrt{2}\approx1.414$ $\quad$ $\sqrt{3}\approx1.732$ $\quad$ $\sqrt{5}\approx2.236$ $\quad$ $\sqrt{7}\approx2.646$ $\quad$ $\pi\approx3.142$ $\quad$ $\mathrm{e}\approx2.718$

Answer all the problems. Problems marked with * are relatively difficult.

Part I Fundamental concepts (13 points)

(A) For each of the following physical quantities, write its unit.

1)	wavelength	**4)**	velocity	**7)**	power
2)	frequency	**5)**	force	**8)**	linear momentum
3)	mass	**6)**	work	**9)**	angular momentum

(B) Choose vector quantities from the above. (Please answer by the label **1**–**9**.)

(C) Fill the blanks. The last three answers (10–12) must be a word starting with "L" (l) or "T" (t).

The equation $x(t) = A\cos(\omega t + \phi)$ describes an __(**1**)__ motion. Here, A is the amplitude, $\omega t + \phi$ is the phase, ω is the __(**2**)__, and ϕ is the phase constant. Its period is given by $T =$ __(**3**)__ and the maximal speed is by $v_{\max} =$ __(**4**)__.

Meanwhile, $y(x,t) = A\cos(kx - \omega t)$ describes a wave. Here, k is the __(**5**)__ and ω is the __(**6**)__. If $\omega > 0$ and $k > 0$, its frequency is given by $f =$ __(**7**)__, wave speed is given by $v =$ __(**8**)__ and its propagating direction is __(**9**)__.

An earthquake results in two seismic waves. The faster one, P wave, is a __(**10**)__ wave and the slower one, S wave, is a __(**11**)__ wave. Electromagnetic waves, i.e., lights, are __(**12**)__ waves.

Part II Motion (10 points)

(A) A 1.0-kg stone is held 5.0 m above the ground and then released from rest. As air resistance is negligible, the stone undergoes free fall for 5.0 m and hits the ground. Calculate the kinetic energy of the stone just before it reaches the ground.

(B) A particle with mass m_{B} is moving in xyz-space. Its position $\vec{r}$ varies in time t according to $\vec{r} = at\vec{e_x} - bt^2\vec{e_y}$, where a and b are positive constants. Find the velocity, acceleration, and kinetic energy of the particle as functions of t.

(C) Another particle with mass m_{C} undergoes a non-uniform circular motion with radius R,

$$\vec{r} = \begin{pmatrix} R\cos\theta(t) \\ R\sin\theta(t) \\ 0 \end{pmatrix}; \qquad \theta(t) \text{ is a function of time } t.$$

Find the velocity and the angular momentum (about the origin) of the particle.

[The exam questions continue on the next page.]

Part III Work and Energy (12 points)

A spring hangs from the ceiling. When a object of mass 1.00 kg is hung vertically on the spring and at rest, the spring stretches 19.6 cm. Assuming the spring obeys Hooke's law and neglecting the mass of the spring, answer the following questions. Use $g = 9.80\,\mathrm{m/s^2}$ for the standard acceleration of gravity.

(A) Calculate the force constant of the spring.

(B) How far will the spring stretch if a 2.00 kg block, at rest, is hung on it?

(C) A boy stretches the spring by 10.0 cm from its unstretched position (with no blocks attached) using his hand. Discuss the amount of work he has done on the spring.

*__(D)__ The boy hangs a block of mass 2.00 kg vertically on the spring. He then pulls the block down and releases it gently. The block moves vertically, going up and down, with an amplitude $A = 10.0\,\mathrm{cm}$. Calculate the maximal speed of the block and the maximal length of the spring during the motion, assuming the natural length of the spring is 2.000 m.

Part IV Collision (15 points)

A car of mass $m_1 = 1.0 \times 10^3\,\mathrm{kg}$ crashes into the back of a truck of mass $m_2 = 5.0 \times 10^3\,\mathrm{kg}$ moving in the same direction. Just before the collision, the car's speed is $v_1 = 1.0 \times 10\,\mathrm{m/s}$ and the truck's speed is $v_2 = 4.0\,\mathrm{m/s}$. They are coupled and move together after the collision.

(A) Explain the difference between elastic collisions and inelastic collisions.

(B) What is the speed of the two vehicles immediately after the collision?

(C) What is the change in kinetic energy of the car–truck system in the collision?

(D) Is this an elastic collision or an inelastic collision? Answer with a reason.

*__(E)__ After the collision, both vehicles' engines and drive system were broken and their tires no longer rotate. Assuming the coefficient of kinetic friction between the road and the coupled vehicles is $\mu_\mathrm{k} = 0.10$, calculate how much distance they travel before they stop.

Part V Extra Problem 1 (10 points)

When two sounds with the frequency $f_1 = 440\,\mathrm{Hz}$ and $f_2 = 439\,\mathrm{Hz}$, respectively, are played together, we feel beating with the frequency $|f_1 - f_2| = 1\,\mathrm{Hz}$. Explain why.

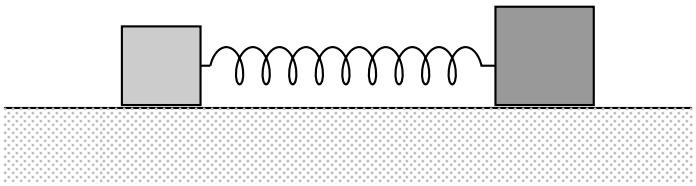
[The exam questions continue on the next page.]

Part VI Extra Problem 2 (unlimited points)

This is an extra challenging problem. You may try writing something for a partial mark, because no penalty is given for incorrect answer as long as you are a student.

Two blocks are attached to the ends of a spring and placed on a frictionless horizontal floor. Initially, they are at rest and the spring is stretched from its natural length. Then, the fixing is gently released and the blocks start moving. Discuss the motion of the blocks.

[Hint: Draw a force diagram, define masses etc., define axes, and write down the equations of motion. Are the total momentum and the energy of the system conserved or not? Discuss why. Where is the center of gravity, and what do we know about its motion?]



[This is the end of the exam questions.]